Exploring Sustainability & Innovation

in the Dutch Concrete Sector

Ryan Netto S4893328

MSC SUSTAINABLE ENTREPRENEURSHIP

05/06/2025

Block 2B (2024-2025)

Thesis Supervisor: Rimvyde Muzikeviciute-Oud, PhD Candidate
Co-assessor: Dr Sven Kilian, PhD
Assessor: Dr Berfu Ünal, PhD

INDEX

9. APPENDICES

A. Interview Guide

B. Consent and Ethics Forms

C. Thematic Coding Structure

ABSTRACT

This qualitative study explores how companies in the Dutch concrete sector engage with sustainability and innovation amid growing pressure to decarbonise. Using the Dutch Concrete Agreement and its Road Map CO_2 as entry points, the research investigates how voluntary frameworks are interpreted and operationalised within diverse organisations. Data were collected through nine interviews across concrete product manufacturing firms. The PROMISE framework was used as a diagnostic lens to examine how structural conditions shape low carbon innovation pathways.

The findings reveal that while the Concrete Agreement sets out sectoral ambition, its influence is mediated by procurement norms, internal leadership, and organisational culture. Client-driven demand, especially through MKI-based tendering, emerged as a key driver of sustainability action. However, fragmented procurement standards, certification ambiguity, and cost barriers continue to limit widespread adoption. Sectoral platforms such as Betonhuis and BouwCirculair were identified as important enablers through their support for knowledge-sharing and alignment of innovation goals.

The study further highlights the potential of emerging technologies such as 3D concrete printing, which offer opportunities for material efficiency and circular design but face challenges in certification and mainstream acceptance. Overall, decarbonisation in the concrete sector is not hindered by a lack of innovation, but by systemic misalignments between voluntary ambition, market signals, and regulatory structures. This thesis offers practical insights for aligning procurement policy, certification frameworks, and organisational readiness to accelerate low-carbon innovation across construction.

1. Introduction

1.1. Background and Problem Statement

The construction industry is a critical contributor to climate change, accounting for approximately one-third of global greenhouse gas emissions (International Energy Agency et al., 2023). These emissions are commonly divided into (1) operational carbon, which is linked to energy use during a building's lifetime; and (2) embodied carbon, which includes emissions generated during the extraction, production, transport, construction, and end-of-life phases of building materials (Rodrigo et al., 2019; Schwartz et al., 2018). As energy performance regulations continue to reduce operational emissions, embodied emissions have grown in relative significance within the construction sector's overall carbon footprint.

In alignment with the 2015 Paris Agreement, which aims to limit global warming to well below 2°C, governments have adopted increasingly ambitious climate goals. At the European level, the Green Deal and the "Fit for 55" package aim to reduce emissions by at least 55% by 2030 compared to 1990 levels (Council of the European Union, 2021). The revised Energy Performance of Buildings Directive (EPBD), for example, mandates whole-life carbon assessments and the renovation of underperforming buildings to meet these goals (Sibileau et al., 2024). In the Netherlands, national commitments under the Climate Agreement outlines binding emissions reduction targets across all sectors, including construction (Government of the Netherlands, 2019).

To accelerate carbon reduction efforts, various policy instruments have emerged. These include market-based mechanisms like emissions trading schemes and carbon credits, which remain underdeveloped in construction, as well as more direct instruments like the CO_2 Performance Ladder which is a procurement-linked certification mechanism widely used in the Netherlands (SKAO, 2025a, 2025b, 2025c; van Tam et al., 2024). Complementing these top-down approaches, sector-led initiatives have also taken shape. One such initiative is the Dutch Concrete Agreement *(Betonakkoord)*, launched in 2018 as a voluntary commitment to reduce CO_2 emissions across the Dutch concrete supply chain (van Gent, 2021). This agreement is coordinated by Betonhuis, the main trade association representing Dutch manufacturers of concrete products, including precast elements, paving materials, and ready-mixed concrete.

Betonhuis played an important role in promoting innovation and aligning industry practices with environmental policy by connecting producers, contractors, and clients with technical knowledge and market intelligence (Betonhuis, n.d.).

The Concrete Agreement was developed through a collaborative, multi-stakeholder process involving government ministries, NGOs, Betonhuis, and other sector actors. Its implementation strategy is outlined in the *Road Map* CO_2 document, which identifies 28 "action perspectives" (*handelingsperspectieven*) for decarbonisation, including strategies such as circular material use, design for disassembly, digital manufacturing, and industrial symbiosis (van Gent, 2021). These guidelines were intended to support companies across the concrete value chain in transitioning toward lower-carbon practices.

In parallel, platforms such as BouwCirculair have emerged to foster systemic change by facilitating regional collaboration among municipalities, contractors, and suppliers towards circular construction practices. BouwCirculair provides practical tools, performance data, and pilot projects to support circular construction, particularly in infrastructure and concrete works (BouwCirculair, n.d.). BouwCirculair aims to translate policy ambitions into concrete, localised actions. These efforts are relevant in the Netherlands, where environmental impact is increasingly measured using life-cycle indicators like the *MilieuPrestatie van Gebouwen* (MPG) covering Environmental Performance of Buildings and *MilieuKostenIndicator* (MKI) covering Environmental Cost Indicator, which assign monetary value to environmental impacts to inform tendering and design decisions (Nationale Milieudatabase, n.d.).

Despite the sector's growing ambition and guidance frameworks, the voluntary nature of initiatives like the Concrete Agreement raises important questions. Implementation depends largely on how individual firms interpret and act upon sectoral decarbonisation goals. While strategies such as self-healing concrete, three-dimensional concrete printing, and reuse of precast elements demonstrate technical promise, they face adoption barriers related to investment cycles, supply chain fragmentation, risk aversion, and a lack of clear incentives in public procurement (Cramer, 2021). Consequently, there is a need to better understand how sector-led frameworks such as those advanced by Betonhuis and BouwCirculair are influencing organisational behaviours, procurement practices, and innovation adoption. Are these initiatives driving meaningful engagement with decarbonisation across the construction ecosystem, or do gaps remain between ambition and implementation?

1.2. Research Aim and Contribution

This exploratory study aims to investigate how companies in the Dutch concrete sector are engaging with sustainability and innovation while addressing decarbonisation. The research is positioned within the broader context of voluntary sectoral initiatives, using the Concrete Agreement which was developed with support from Betonhuis as a strategic entry point for examining how companies interpret and respond to emerging expectations around carbon reduction. Instead of assessing the effectiveness of specific policy instruments, the study takes an explorative approach, focusing on how companies make sense of decarbonisation goals, and how this understanding translates into innovation practices while including materials, processes, and organisational strategies. Therefore, this study is guided by the following research question and subquestions:

"How are companies in the Dutch concrete sector engaging with sustainability and innovation while addressing decarbonisation?"

1. How do Dutch companies approach sustainability in relation to decarbonisation?
2. What innovations are being explored and/or adopted to support this engagement?

To guide this analysis, the study applies the PROMISE framework (Kukah et al., 2025), which identifies six dimensions such as personal, relational, organisational, market, institutional, social and environmental practices to collectively determine whether innovations are supported or excluded within a given system. Using PROMISE allows this research to explore the systemic conditions that affect the adoption of innovations such as those outlined in the Concrete Agreement's *Road Map* CO_2.

1.3. Thesis Structure

This thesis is structured into seven sectons. Section 1 introduces the background of the study, formulates the research problem, outlines the research aim, and presents the central research question along with two subquestions. Section 2 presents a literature review, examining scholarly research on embodied carbon, low-carbon innovation, circular construction, and the systemic barriers faced by the concrete sector. Section 3 introduces the theoretical background, including sustainability transition and the PROMISE framework, which is used as an analytical lens. Section 4 describes the research design and methodology, including case selection, data collection through interviews, and the application of thematic analysis. Section 5 presents the findings, structured around five themes derived from PROMISE, highlighting how firms interpret and respond to decarbonisation strategies. Section 6 discusses these findings in relation to existing literature and theory, reflects on the implications for innovation and sectoral governance, and addresses the study’s limitations. Finally, Section 7 concludes the thesis by summarising key insights, discussing contributions to theory and practice, and proposing directions for future research.

2. LITERATURE REVIEW

This section reviewed academic literature relevant to sustainability transitions, low-carbon innovation, and systemic enablers and barriers in the concrete sector. It begins by examining the growing concern around embodied carbon and the climate impact of concrete. It then reviews studies on low-carbon materials and circularity in construction, followed by a discussion of structural and institutional factors that influence innovation. Finally, the section explores sector-led initiatives in the Netherlands and identifies a gap in the literature on how companies interpret and act on voluntary decarbonisation strategies, then laying the groundwork for the theoretical background in section 3.

2.1. Embodied Carbon and Sustainability in Concrete

As building energy efficiency improves, embodied carbon emissions associated with material production, transport, construction, and end-of-life processes have emerged as a major share of a building's total environmental impact. Cement, the key binder in concrete, is particularly carbon-intensive, contributing up to 90% of concrete's total emissions (Rodrigo et al., 2019). Globally, the cement and concrete industry accounts for approximately 8% of anthropogenic CO_2 emissions (Schwartz et al., 2018). Recent policy attention, including the European Green Deal and Dutch Climate Agreement, has shifted toward life-cycle carbon accounting (Council of the European Union, 2021; Government of the Netherlands, 2019). In low-energy buildings, embodied emissions can constitute up to half of total emissions over the asset's lifetime (Rodrigo et al., 2019). These developments showcase the need to decarbonise the concrete supply chain through both technical innovation and systemic change.

2.2. Low-Carbon Innovation in Concrete

Academic literature has identified a broad set of strategies to reduce the carbon footprint of concrete. These include replacing traditional cement with supplementary cementitious materials, using alternative binders such as geopolymer or alkali-activated cements, increasing the use of recycled aggregates, and incorporating digital methods such as three-dimensional concrete printing (3DCP) (Habibi et al., 2024; Kemp et al., 2017; Rodrigo et al., 2019).

Clinker-reduced products like Cement three (CEM III) and geopolymer concrete have demonstrated emissions savings ranging from 30% to 80% depending on application (Kemp et al., 2017). 3DCP is viewed as a way forward for reducing material use through geometrical optimisation, material customisation and monitoring (Habibi et al., 2024). Despite their technical maturity, these innovations appear underutilised and likely constrained by regulation, market conservatism, and procurement process (Rodrigo et al., 2019). This discrepancy between available technologies and their real-world adoption points to broader systemic constraints that go beyond material performance.

2.3. Circularity and Reuse in Concrete Construction

Beyond material innovation, circular economy principles have gained prominence in reducing resource extraction and construction waste. In concrete, this includes reuse of aggregates from demolition, modular design, and prefabrication methods that support future disassembly (van Oorschot et al., 2023). Circular practices aim not only to cut emissions but also to extend material life and reduce dependence on virgin resources. Studies in the Dutch context suggest that combining renovation with material reuse and biobased alternatives yields lower life-cycle carbon impacts than most new builds (van Oorschot et al., 2023). However, implementation could be limited by practical and institutional constraints, such as variable material quality, unclear standards, differing municipal policies, and lack of client demand (Kemp et al., 2017; Cramer, 2021). Although circularity is widely referenced in both policy and academic discourse, its adoption in the Dutch concrete sector depends on aligning technical feasibility with regulatory clarity and procurement incentives.

2.4. A Concrete Initiative

In response to these challenges, the Dutch concrete industry introduced the Betonakkoord in 2018, a voluntary agreement developed through collaboration among the industry's associations, NGOs, and government actors. It outlined climate and circularity ambitions, with

Betonhuis playing a role in coordination and implementation. One of the Betonakkoord's key tools is the *Road Map CO_2*, a document that presents 28 action perspectives for emission reduction, including recommendations on alternative binders (e.g. CEM III), digitalisation (e.g. 3DCP), reuse strategies, and carbon monitoring (van Gent, 2021). While the roadmap offered structure and ambition, it was non-binding. So the sector's participants were free to interpret and implement its guidance based on their capacities.

Betonhuis supported this implementation through technical advice, working groups, and policy alignment. Some companies proactively adopted innovations aligned with the roadmap, including certification schemes and circular procurement pilots. Others remained cautious, citing regulatory uncertainty, cost concerns, or limited client demand (Cramer, 2021). While the Betonakkoord provided decarbonisation direction, it was not wholly adopted sector-wide. Academic literature has not yet extensively examined how these companies engaged with such voluntary strategies in practice. Most studies above focused on policy ambition or material performance rather than how innovation is navigated on the ground. This presents a gap for empirical investigation.

3. THEORETICAL BACKGROUND

This thesis does not treat the Betonakkoord or Road Map CO_2 as theoretical models. Instead, they serve as empirical entry points for analysing how organisations interpret, respond to, and operationalise sustainability expectations under voluntary conditions. To do this, the study adopts a systemic theoretical lens rooted in innovation and transition literature.

3.1. Adoption through Innovation and Transition

Innovation in the built environment rarely depends on technology alone. Instead, it unfolds within complex systems shaped by policy, market incentives, professional routines, and regulatory structures (Geels, 2011; Kemp et al., 2017; Kivimaa & Kern, 2016). Research on sustainability transitions has shown that technical feasibility is only one factor among many influencing the diffusion of innovation. In construction, even well-developed solutions such as low-carbon binders or modular design can struggle to scale due to institutional limitations, value chains, and procurement processes (Rodrigo et al., 2019; van Oorschot et al., 2023). The multi-level perspective introduced by Geels (2011), frames transitions as interactions between three levels: niches (protected spaces for experimentation), regimes (dominant systems of practice), and landscapes (wider external pressures). Innovations like geopolymer concrete may emerge in niches but often struggle to penetrate regimes due to structural resistance including rigid compliance codes, risk-averse clients, or supply chain constraints.

Kivimaa and Kern (2016) argue that effective transitions require a policy mix that not only supports emerging alternatives but also actively destabilises incumbent systems. This could be relevant in the concrete sector, where long-standing practices, institutional conservatism, and regulation could be barriers to change (Cramer, 2021). Kemp et al. (2017) extend this view by highlighting how for technologies and institutions, innovation is not simply about better products, but also about aligning organisational strategies, norms, and rules. Without supportive institutional adaptation, even well-proven innovations can be excluded from mainstream practice. These theoretical perspectives present the need to understand adoption in the concrete sector alongsde the interaction between actors, rules, technologies, and routines.

3.2. The PROMISE framework

The PROMISE framework developed by Kukah et al. (2025) was designed to examine how sustainability-oriented innovations can be structurally excluded from adoption despite their alignment with climate goals. It responds to the need for an analytical model that captures not only supportive mechanisms but also the systemic misalignments that inhibit innovation across sectors. PROMISE builds on earlier systems-thinking work, including the version introduced by Jason Jay at MIT Sloan (2015), which emphasised the interaction between personal, organisational, and institutional dynamics in advancing sustainability strategies. While Jay's version was primarily applied in executive education and strategic facilitation, Kukah et al. (2025) adapted PROMISE (see Figure 1) into a research-oriented diagnostic framework tailored to the complexities of carbon emissions governance and innovation systems. Outlining six interconnected domains of Policy, Regulation, Market, Organisation, Institution, and Socio-technical Practices that influence whether innovations are supported or excluded. For example, a company may face strong policy pressure to reduce emissions, yet adoption may still stall if procurement remains price-driven or if regulatory approvals lag behind technical developments (Kukah et al., 2025). PROMISE enables researchers to trace these dynamics systematically, making it especially relevant in complex transition contexts.

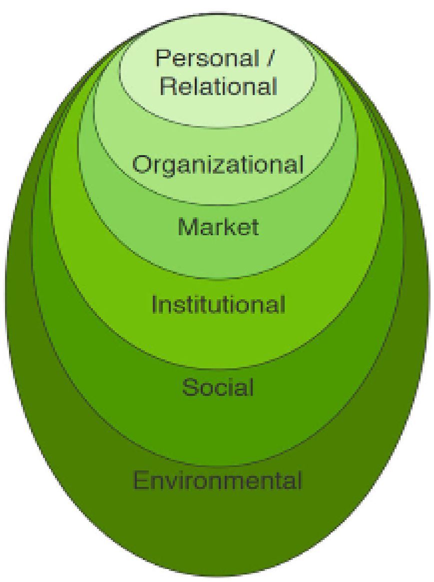

Figure 1. MIT Sloan (Jay, 2015); Kukah et al. (2025)

In the Dutch concrete sector, this structure is useful. The Betonakkoord articulates a shared sustainability vision, but companies operate across diverse project types, client expectations, and organisational capacities (Cramer, 2021). PROMISE offers a way to examine how such contextual variation influences the uptake of low-carbon practices and innovations promoted in the Road Map CO_2 (van Gent, 2021). This thesis uses PROMISE as a diagnostic lens to analyse how Dutch concrete companies interpret and respond to voluntary sustainability strategies. It informed the design of the interview guide and served as the basis for thematic coding. By organising findings according to PROMISE domains, the study explores not only whether firms adopt low-carbon innovations, but how they navigate uncertainty, procurement trade-offs, and internal limitations.

While PROMISE was previously used in carbon emissions trading and procurement contexts (Kukah et al., 2025), its application to voluntary, sector-led innovation strategies in materials-intensive industries like concrete is new. This study therefore extends the framework's use and demonstrates its relevance in diagnosing both barriers and enablers at the organisational level, offering insight into the systemic alignment or misalignment that shapes sustainability transitions in practice.

3.3. Research Gap and Analytical Implications

As decarbonisation strategies for concrete have been outlined in the previous section, less is known about how companies in the sector interpret and act on these frameworks. Most research addresses the availability of low-carbon technologies or the regulatory goals driving climate policy. Few studies examine the organisational dynamics and systemic conditions that shape innovation at firm level, especially in the context of non-binding, sector-led strategies like the Betonakkoord. This thesis addresses that gap by applying the PROMISE framework (Kukah et al., 2025), which enables analysis of how policy, regulation, markets, organisations, institutions, and socio-environmental practices interact to support or constrain low carbon innovation. PROMISE allows a deeper understanding of how Dutch concrete companies engage with low-carbon transitions in practice, not just whether they comply, but how they navigate, interpret, and act upon sectoral decarbonisation efforts. The next section introduces the theoretical background, specifically the PROMISE framework, and explains how it supports the research design and analytical approach.

4. METHODOLOGY

4.1. Case Study Design

This exploratory study adopts a qualitative case study approach to investigate how companies in the Dutch concrete sector engage with sustainability and innovation while addressing decarbonisation. A case study design (see figure 2) is appropriate for examining real-life phenomena within their specific, complex contexts, where boundaries between the phenomenon and context are not clearly defined (Creswell, 2009). This makes it suitable for understanding how companies interpret and act upon voluntary sustainability strategies such as the Betonakkoord and its Road Map CO_2.

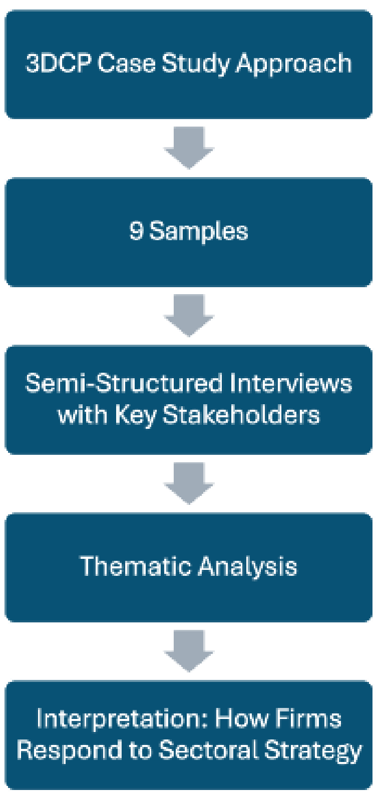

Figure 2. Case Study Approach

The exploratory research is situated within a constructivist paradigm, which assumes that knowledge is co-produced through interaction and is socially and institutionally embedded. This philosophical foundation aligns with the aim of exploring how stakeholder perspectives, internal strategies, and sectoral conditions influence innovation adoption. Rather than seeking universal truths, the goal is to generate context-rich insights into how sustainability and innovation practices are framed and implemented within concrete-producing firms.

In terms of analytical method, this study applies reflexive thematic analysis as outlined by Braun and Clarke (2006). This approach is suitable for identifying patterns of meaning across stakeholder interviews while allowing for both inductive (emerging) and deductive (framework-guided) coding. Reflexivity is key to this method, requiring the researcher to engage critically with their positionality and interpretive role throughout the analytical process. This research combines a qualitative case study design with thematic analysis, guided by the PROMISE framework, to generate empirically grounded insights into how systemic conditions shape low-carbon innovation in the Dutch concrete sector.

4.2. Case Context: 3DCP Company from North Brabant

The case study was conducted in collaboration with a startup based in North Brabant, the Netherlands, specialising in 3DCP. The company has played a pioneering role in Dutch 3DCP applications, including early bridge prototypes, positioning itself at the forefront of low-carbon, digitally enabled construction. Operating within the region's high-tech innovation ecosystem which is home to global leaders like Philips and ASML, the case integrates robotics, structural engineering, and architectural design to develop scalable additive manufacturing methods for the built environment. The company's mission aligns with broader efforts to digitise and decarbonise the construction industry. Its team combines expertise in automation, materials science, and sustainability, and has participated in both public and private innovation initiatives for over five years. Its activities reflect an effort to address key structural issues in the construction sector, including labour intensity, low productivity, and environmental impact. It functions as a niche innovator, offering a highly relevant context for examining how real-world practices interact with sector-level transition strategies such as the Betonakkoord and its Road Map CO_2.

4.3. Stakeholder Categories and Sampling

The study focused on three company types within the Dutch concrete sector, as per the Betonhuis.com:

1. **Traditional construction firms** – Large-scale contractors using conventional materials and methods, offering insight into how legacy practices align with or challenge low-carbon transition goals.
2. **Prefab construction firms** – Companies working with off-site modular production, often viewed as more controlled environments for testing low-carbon solutions.
3. **3D concrete printing firms** – Highly experimental organisations at the frontier of digital fabrication and automation, highlighting both technological promise and regulatory or institutional barriers.

This typology was used to ensure a diverse and comparative understanding of how different production modes engaged with sustainability and innovation. These categories reflected varying degrees of innovation maturity, operational flexibility, and exposure to decarbonisation strategies. Purposive sampling continued until thematic saturation was reached, meaning no new conceptual insights emerged from additional interviews (Braun & Clarke, 2006; Creswell, 2009).

Interviewee	Medium	Description
1	Online - English	Sustainability advisor
2	Online - English	Sales representative
3	Online - English	Sales & marketing manager
4	In-person - English	Fourth-generation director of one of the largest family-run organisations
5	In-person - English	Product & Innovation Manager (PhD)
6	Online - Dutch	Sales Manager
7	Online - Dutch	Fourth-generation director of a small family-run organisation
8 9	Online - English	Sales & marketing manager Sustainability advisor
10	Online - English	Fourth-generation director of a large family-run organisation

Table 1. Participant Details

The participants (see table 1) were contacted via email after receiving their publicly listed contact details on betonhuis.com. This study focused on nine companies operating within the Dutch concrete sector and part of Betonhuis, selected through purposive sampling based on their relevance to the research aims. The sampling strategy was designed to capture a range of organisational types, market segments, and innovation profiles, including firms involved in precast concrete, paving, infrastructure components, sewerage, and experimental applications such as 3D concrete printing.

4.4. Data Collection: Thematic Interviews

Primary data were collected through semi-structured, in-depth interviews with stakeholders from 9 companies across the Dutch concrete sector. The interviews were conducted in May and June 2025, two in person and seven online, depending on participants' availability. Seven online interviews took place via Microsoft Teams, while the other two were conducted at the interviewees' locations. Seven interviews lasted between 40 and 50 minutes, while the other 2 interviews lasted between 60 and 70 minutes. Interviews were audio-recorded with consent, transcribed verbatim, and anonymised. The interviewees signed the information and consent prior to the interviews, and they were made aware of the outcome of their participation. Two online interviews were conducted in Dutch as per request from the interviewees, while the rest were conducted in English.

The interviews followed an interview guide structured around key themes derived from the PROMISE framework and the Road Map CO_2 (see figure 3 for a representation of 28 strategies), including sustainability engagement, innovation adoption, perceived barriers and enablers, and the perceived role of sectoral decarbonisation strategies. The interview guide also included exploratory prompts to allow for unanticipated insights to emerge. It comprised 12 main questions,that facilitated going in depth into low-carbon adoption and implementation of Betonakkoords Road Map CO_2. This supported a balance between comparability across cases and the flexibility to capture diverse organisational perspectives.

Action	Roadmap CO_2 Description	Roadmap CO_2 Omschrijving	Testing	Implemented (Y)	Not Implemented (N)	Not Applicable (N/A)
1	Optimize the grain size distribution of aggregates to reduce voids and minimize cement use.	Optimaliseer korrelverdeling van toeslagmaterialen om holle ruimtes te beperken en cementgebruik te verlagen.				
2	Use low-CO_2 Belite clinker cement types like CSA or BCT to reduce emissions in cement production.	Gebruik Beliet-gebaseerde cementen zoals CSA of BCT met lagere CO_2-uitstoot bij productie.				
3	Apply alternative binders like Solidia that absorb CO_2 during curing for additional environmental benefits.	Pas alternatieve bindmiddelen toe, zoals Solidia, die CO_2 opnemen tijdens het uitharden.				
4	Implement carbon capture technologies at cement plants to reduce process emissions.	Voer CO_2-afvang uit bij cementproductie om procesemissies te verminderen.				
5	Use geopolymers made from industrial by-products as low-carbon alternatives to traditional cement.	Gebruik geopolymere bindmiddelen op basis van reststoffen als alternatief voor cement.				
6	Design buildings and elements for future disassembly and reuse instead of demolition.	Ontwerp gebouwen en elementen zodanig dat toekomstige demontage en hergebruik mogelijk is.				

Figure 3. Six out of 28 Strategies (Representative Betonakkoord Road Map CO_2)

These cases illustrated variation in how sustainability and innovation were understood and implemented across the concrete sector. While some firms actively engaged with the Concrete Agreement, others pursued low-carbon strategies independently of formal frameworks. The data was gathered from knowledgeable stakeholders within each company, including directors, sustainability advisors, technical managers, sales and marketing managers, etc, who are involved in both strategy and implementation. Their perspectives provided insight into how organisational decisions were shaped within specific market and regulatory conditions. This context provided access to a network of relevant companies and helped ensure that participants were well-positioned to speak to innovation challenges in the sector. To complement the interview data, additional secondary sources were consulted, including company sustainability reports, Road Map CO_2 documentation, and relevant policy publications, to provide contextual background.

4.5. Thematic Analytical Approach

This method was selected for its suitability in identifying and interpreting patterns of meaning across a qualitative dataset, particularly in exploring how companies engage with sustainability and innovation in the context of voluntary decarbonisation efforts.

Rather than assuming objective or fixed realities, the analysis prioritised how stakeholder accounts constructed meaning around sustainability, innovation, and systemic constraints. The PROMISE framework served as a sensitising concept, guiding theme development without imposing rigid categories. This allowed the study to remain open to emergent insights while also examining systemic dimensions such as regulation, procurement, and organisational strategy.

Transcripts were produced using Microsoft Word, with attention to compliance with General Data Protection Regulation (GDPR) requirements. Coding and thematic development were organised in Excel and visualised using thematic maps. While qualitative analysis software ATLAS.ti was explored, manual coding was retained to preserve interpretive flexibility. Coding was carried out by the researcher, with periodic peer discussions used to enhance reflexivity and transparency.

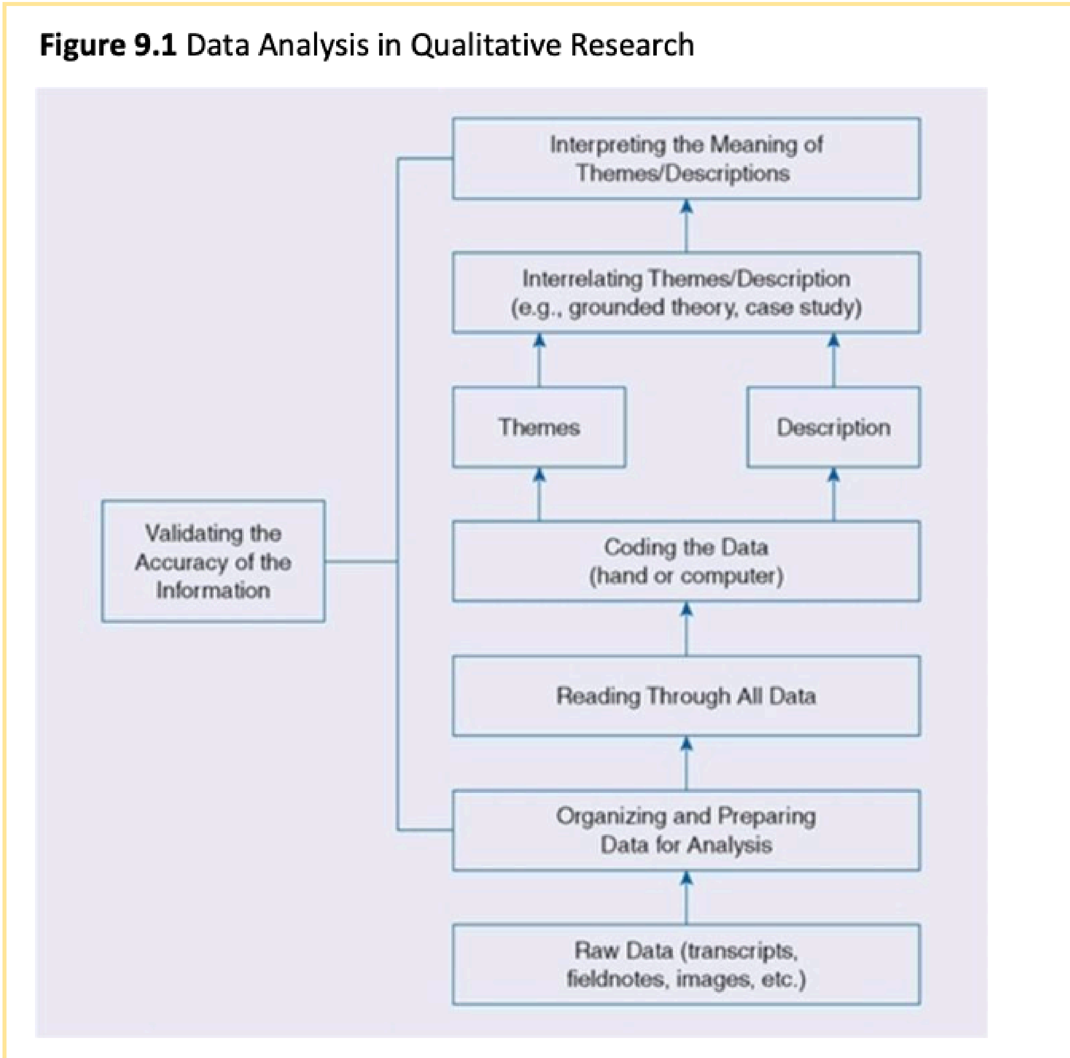

Figure 4. Analysis Process (Creswell, 2009)

This analysis is grounded in a constructionist epistemology, which assumes that meanings are socially produced and context-dependent. Therefore, rather than assuming objective or fixed realities, the analysis (see figure 4) prioritised how stakeholder accounts constructed meaning around sustainability, innovation, and systemic constraints. The PROMISE framework served as a sensitising concept, guiding theme development without imposing rigid categories. This allowed the study to remain open to emergent insights while also examining systemic dimensions such as regulation, procurement, and organisational strategy.

Transcripts were produced using Microsoft Word, with attention to compliance with General Data Protection Regulation (GDPR) requirements. Coding and thematic development were organised in Excel and visualised using thematic maps. While qualitative analysis software ATLAS.ti was explored, manual coding was retained to preserve interpretive flexibility. Coding was carried out by the researcher, with periodic peer discussions used to enhance reflexivity and transparency.

4.6. Trustworthiness and Ethical Considerations

To ensure the integrity of the research, multiple strategies were employed to support credibility, dependability, confirmability, and transferability of findings. During the interviews, clarification probes and member reflections were used to confirm key insights and reduce misinterpretation. Opportunities were created during each interview for participants to expand on or revise their statements. A logbook of analytical decisions, such as code refinements and theme adjustments, was maintained to enhance transparency. Contextual descriptions were used in the write-up to support interpretive depth and enable readers to assess the transferability of insights to similar industry settings. Parts of the study utilised writing tools, including Google Translate and ChatGPT, for further textual enhancement and refinement.

Ethical approval was obtained through the MSc Sustainable Entrepreneurship programme. All interviewees provided informed consent prior to participation. Interviews were audio-recorded (with explicit permission) and transcribed verbatim. Data were anonymised during transcription and stored securely on password-protected and encrypted devices. All procedures were conducted in compliance with GDPR and the university's ethics policy. These measures ensured that participants' privacy was protected and that the research was conducted with transparency and professional responsibility throughout.

5. RESULTS

This section presents the findings derived from interviews with eight organisations in the Dutch concrete sector. The data provides insight into how participatnts interpret and implement sustainability and innovation practices in relation to voluntary decarbonisation frameworks. The results are structured across five main themes, each grounded in the PROMISE framework and developed through thematic analysis.

5.1. Stakeholder Awareness & Understanding of the Concrete Agreement

The findings revealed significant variation in how stakeholders engaged with the Betonakkoord and the accompanying Road Map CO_2. While some organisations reported active involvement in sector initiatives, others were either unfamiliar with the framework's specifics or considered it peripheral to their daily operations.

Participant 2 described formal engagement through internal working groups facilitated by Betonhuis and noted that the roadmap served as a reference for sustainability planning. However, they also observed disparities in commitment across regional branches within their organisation (Interview 2). Participant 4 acknowledged the ambition of the Betonakkoord but characterised it as having produced "more bureaucracy than improvement," questioning its practical impact (Interview 4). Similarly, Participant 7, operating in the paving segment, dismissed the framework as "a bit of drama," citing unrealistic expectations regarding CO_2 caps (Interview 7).

Participant 5 expressed scepticism regarding the agreement's origins, suggesting it had been driven more by individual or political agendas than by a shared systemic vision (Interview 5). While client expectations were consistently identified as the primary motivator for sustainability practices, Participants 1 and 6 reported that the roadmap held limited operational influence. For them, it functioned more as contextual background, subordinate to client-driven requirements and Betonhuis-led coordination (Interviews 1 and 6).

Across cases, Betonhuis was consistently identified as the more influential actor in shaping sustainability discourse, procurement norms, and technical alignment within the sector. The Betonakkoord itself was often described as symbolic or aspirational, with limited enforcement capacity. Its perceived influence depended largely on a company's position in the value chain, institutional relationships, and exposure to market pressures.

5.2. Strategic Value and Client-Driven Decarbonisation

Participants consistently framed decarbonisation as strategically valuable when aligned with market dynamics, particularly in relation to public procurement and reputational positioning. Although national frameworks such as the Betonakkoord and Road Map CO_2 provided overarching direction, decision-making was predominantly shaped by client demands and project-specific requirements. Participant 1 emphasised that sustainability had become essential for remaining competitive in public tenders, stating, "If you're not sustainable, you're unable to sell your product" (Interview 1). However, they also noted inconsistencies in environmental criteria across municipalities, which created uncertainty for suppliers. Participant 2 confirmed that sustainability efforts were primarily client-driven but were constrained by internal resistance and narrow profit margins. They explained that innovations needed to remain within 10% of baseline costs to be considered viable (Interview 2).

Participant 3 adopted a more anticipatory strategy, aligning its innovation agenda with the Paris Agreement even in the absence of immediate client pressure. This proactive stance was described as a deliberate move to gain first-mover advantage and secure future market positioning (Interview 3). Participant 4 also reported increased attention to environmental metrics such as the MKI in tenders, though they expressed concern about fluctuating client expectations and the administrative burden of compliance (Interview 4). Cost-related barriers were a recurring theme. Participant 5 critiqued the Betonakkoord's benchmarks as detached from financial and operational realities, particularly for smaller producers. They argued that sustainable materials often carried a price premium that compromised competitiveness (Interview 5). Participant 6 described the adoption of cement-free concrete as part of a broader sustainability leadership strategy, highlighting its branding value. However, they noted that such efforts were only recognised if municipalities incorporated sustainability criteria into procurement decisions (Interview 6).

Participant 7 prioritised cost-efficiency and viewed sustainability investments as contingent on client co-funding or explicit requirements. They remarked, "If it is not cheaper or does not benefit your cost price [...] there is actually no point in doing it" (Interview 7). In contrast, Participants 8 and 9 viewed sustainability as part of a long-term organisational strategy. Their approach focused on certifications and circularity initiatives that extended beyond immediate client requests. They positioned sustainability as a form of future-proofing aligned with evolving sectoral norms and stakeholder expectations (Interview 8). Overall, the data indicated that while environmental goals were broadly acknowledged, concrete action depended heavily on whether sustainability offered a strategic or commercial advantage which typically mediated through public procurement frameworks or client mandates.

5.3. Institutional and Market Barriers

Although participants expressed a general commitment to sustainable innovation, they consistently identified a range of institutional and market-level barriers that limited their ability to implement decarbonisation strategies. These included fragmented regulation, inconsistent procurement standards, technical limitations, conservative client behaviour, and a lack of financial incentives. Regulatory fragmentation emerged as a key constraint. Participant 1 highlighted that sustainability expectations varied significantly between municipalities, resulting in inconsistent environmental criteria across public tenders (Interview 1). This sentiment was echoed by Participant 6, who described the Dutch procurement system as overly complex in comparison to neighbouring countries like Germany, suggesting that excessive regulation had become a barrier to innovation rather than a catalyst (Interview 6).

Technical limitations were another widely cited challenge, particularly for firms working with reinforced concrete or standardised prefabricated systems. Participant 5 noted that while cement substitutes were promising, their applicability in load-bearing or high-precision components remained restricted due to concerns over quality and reliability (Interview 5). Participant 7 added that attempts to increase recycled aggregate content could inadvertently raise cement dosage requirements, thereby negating environmental benefits and increasing overall carbon emissions (Interview 7). Client conservatism was also identified as a structural impediment. Several participants observed that although sustainability was frequently discussed, it was rarely prioritised in actual project delivery unless tied to clear financial or regulatory incentives.

Participant 5 described clients who expressed interest in sustainable products but were unwilling to pay a premium for them (Interview 5). Participant 2 similarly noted that internal teams were hesitant to adopt greener materials in the absence of compelling cost-benefit justification (Interview 2). Participants 4 and 8 drew attention to the lengthy approval processes required for alternative materials (Interview 4; Interview 8). They reported that the absence of standardised guidelines for secondary materials created delays, especially for newer, bio-based or "hyped" innovations that lacked robust technical validation. This regulatory and institutional uncertainty discouraged experimentation and slowed adoption timelines.

Finally, participants agreed that limited financial incentives constrained the business case for sustainability. Although there was widespread interest in adopting low-carbon practices, companies reported that current policy instruments and tendering systems did not sufficiently reward early movers or offset the risks associated with innovation. Overall, the findings indicate that despite growing awareness and strategic intent, firms operated within an institutional environment that often constrained rather than enabled transformative change.

5.4. Opportunities and Enablers

Despite the constraints outlined in the previous section, participants also identified a range of enablers that supported or had the potential to accelerate low-carbon innovation in the Dutch concrete sector. These opportunities were rooted in changing client behaviour, enhanced sectoral coordination, and evolving technological capabilities.

Public procurement emerged as the most consistent enabling factor. Participants noted that when municipalities incorporated explicit sustainability criteria such as MKI thresholds, CO_2 performance scoring, or certification standards which all could effectively shift decision-making toward greener alternatives. All participants acknowledged that in some cases, environmental performance now outweighed cost considerations in awarding tenders. However, this influence remained dependent on how clearly and consistently sustainability requirements were defined at the municipal level. Sectoral coordination platforms, particularly Betonhuis and BouwCirculair, were widely recognised as important intermediaries. Participants highlighted the value of participating in working groups and knowledge-sharing sessions, which enabled concrete producers, contractors, and suppliers to align expectations and address shared operational challenges. These forms of peer engagement were seen as essential for bridging the gap between policy ambition and practical implementation.

Certification systems and voluntary frameworks also played a legitimising role. While not universally adopted, tools such as the Concrete Sustainability Council (CSC) certification were viewed as helpful in credibly communicating environmental performance to clients (Concrete Sustainability Council, n.d.). MKI scoring frameworks, although variably interpreted, provided a basis for comparing material options and assessing trade-offs. Participant 10 remarked on the overwhelming number of sustainability certifications available, over 400 in the Netherlands, and explained that their company ultimately selected three certifications, in contrast to some competitors who pursued as many as 25 (Interview 9). This highlighted the challenge of navigating fragmented standards, but also the potential for firms to build credibility through selective adoption.

Circularity and material innovation presented additional opportunities. Participants 3 and 6 described efforts to create closed-loop production systems by reusing concrete granulates or substituting virgin sand with local industrial by-products (Interview 3; Interview 6). These initiatives not only reduced environmental impact but also offered unique branding advantages and new revenue models. Participant 3 emphasised that early investment in material innovation allowed their company to gradually embed circular construction principles into operational workflows (Interview 3).

Internal leadership also emerged as a critical enabler. Several participants pointed to the influence of individuals within their organisations who championed testing, piloting, or upscaling sustainable products (Interview 9). These internal advocates often made the difference between stagnation and progress. While sector-wide transformation remained difficult for concrete, a combination of public-sector signalling, cross-organisational learning, and internal experimentation allowed firms to take meaningful steps toward decarbonisation. Overall, these enablers were more relational and practice-based than formal or top-down. Rather than relying solely on regulation, firms advanced sustainability through networks, experimentation, and proactive interpretation of evolving market signals.

5.5. Organisational Readiness and Innovation Culture

The interviews revealed variation in how companies internally positioned sustainability and innovation. Organisational readiness for decarbonisation appeared closely linked to leadership commitment, internal communication, and whether sustainability was embedded into daily operations or viewed primarily as an external compliance issue.

Leadership buy-in emerged as a critical factor. Participant 10 emphasised that decarbonisation efforts gained momentum only when explicitly supported by senior management (Interview 9). Similarly, Participant 1 highlighted the role of internal communication in maintaining alignment across departments (Interview 1). These insights suggested that internal culture played a significant role in shaping whether innovation was perceived as a strategic priority or a reactive obligation.

Nonetheless, some patterns were observable. Participants 8 and 9 (Interview 8) demonstrated characteristics of transitional organisations: sustainability was incorporated into broader strategy, and innovation was approached incrementally but purposefully. Participant 2 appeared more proactive, seeking to align internal initiatives with client expectations and environmental goals despite facing internal constraints. In contrast, Participant 5 reflected a more pragmatic stance, focusing on compliance and feasibility rather than premature business process transformation. Overall, the findings suggest that organisational readiness is shaped by both internal dynamics and sectoral pressures. While formal strategies and technical solutions are important, the cultural framing of sustainability within firms significantly influences how innovations are adopted and implemented.

6. DISCUSSION

6.1. Interpretation of Findings in Relation to Literature

This study contributes to ongoing debates in sustainability transitions literature by demonstrating that the adoption of low-carbon strategies in the Dutch concrete sector is shaped more by market responsiveness and institutional alignment than by voluntary frameworks alone. Although the Betonakkoord sets an aspirational agenda for sector-wide decarbonisation, its impact on firm-level behaviour remains modest. As Kivimaa and Kern (2016) argue, effective transitions require a “policy mix” that not only supports innovation but also destabilises incumbent practices. The Betonakkoord, by contrast, lacks binding enforcement or direct economic levers, reinforcing Rodrigo et al. (2019) finding that symbolic governance often falls short of delivering material change.

The interviews revealed that the procurement exercise of MKI thresholds often acted as practical enablers of sustainability, even without being formal legal requirements. This aligns with Cramer (2021), who suggests that market-based instruments can institutionalise sustainability when embedded in procurement norms. Yet, this influence was inconsistent, confirming the fragmented nature of governance in the sector. Participant accounts showed that municipal procurement standards varied significantly, a dynamic also observed by van Oorschot et al. (2023), who highlight how local governments can act as both enablers and inhibitors of circular construction.

This research reinforces the PROMISE framework (Kukah et al., 2025) by showing how misalignments across systemic dimensions restrict innovation uptake. In the policy/regulatory domain, the voluntary nature of the Betonakkoord limits enforceability and accountability. In the market domain, disparities in tender practices and limited financial incentives weaken the business case for sustainable alternatives. At the organisational level, only those with committed leadership and sufficient internal capacity were able to implement or pilot low-carbon innovations. In terms of socio-technical norms, entrenched engineering standards and fragmented certification frameworks made it difficult to scale or standardise the use of new materials.

While much of the literature focuses on regulatory and technological aspects of transition, this study contributes by highlighting the relational and networked dimensions of change. Participants frequently cited knowledge-sharing platforms like Betonhuis and BouwCirculair as informal but crucial enablers. This supports the argument by Geels (2011) that innovation is not merely technical but deeply embedded in socio-institutional arrangements. The findings also affirm Kemp et al. (2017) view that co-evolution between market demand, governance, and internal organisational culture is essential for embedding low-carbon practices.

In sum, the results show that decarbonisation in the concrete sector is not hindered by a lack of awareness or ambition, but by structural misalignments across actors and systems. Voluntary frameworks like the Betonakkoord can offer vision, but they must be accompanied by institutional mechanisms, procurement signals, certification consistency, and financial incentives to translate ambition into transformation.

6.2. Implications for Sustainability and Innovation

The results suggest that the Betonakkoord's ambition must be complemented by stronger alignment between public procurement and innovation policy. Tendering standards that reward life-cycle performance such as MKI scoring can amplify early signals of change and incentivise sustainable practices. In parallel, ensuring that secondary materials use and circular innovations can be recognised as freely applicable and standardised within regulatory frameworks would help reduce adoption barriers and enable wider market uptake (Interview 8).

Sectoral platforms notably Betonhuis and BouwCirculair emerged as critical intermediaries. By coordinating working groups, aligning material standards, and facilitating best-practice exchange, these bodies help translate national climate goals into operational reality. Their continued involvement is essential for diffusing innovation, reducing uncertainty, and fostering shared learning within the sector.

At the organisational level, leadership commitment and a culture of experimentation were key enablers of progress. Firms that demonstrated a willingness to pilot new materials or invest in circularity often did so under the influence of proactive leadership and internal champions. However, these efforts remained vulnerable to procurement structures that failed to reward environmental performance or de-risk early adoption.

These insights were further informed by the researcher's internship with a startup in 3D concrete printing. Although not a major focus of the interviews, 3DCP is identified in the Road Map CO_2 as a low-carbon innovation pathway due to its potential to reduce material use, enable geometric optimisation, and localise production. The startup context revealed how smaller, agile firms can pursue experimental approaches more freely than established players. Yet, these innovators face structural constraints: uncertain certification pathways, limited inclusion in procurement frameworks, and scepticism from conservative clients. Larger firms often viewed 3DCP as speculative or high-risk, reinforcing a broader sectoral reluctance to engage with disruptive technologies. This example highlights the need for more targeted support, not only for proven solutions, but also for emerging innovations that require time, trust, and systemic support to scale.

The findings also underscore that enabling decarbonisation is not only about supporting technological readiness but also about building the institutional and organisational environments in which innovation can take root. This includes allowing room for trial and error, investing in knowledge-building networks, and promoting long-term partnerships between firms, clients, and public actors. In this context, policy should aim not just to reward outcomes but to foster the conditions that make innovation possible in the first place.

Ultimately, a balanced approach that combines market signals, regulatory clarity, and peer-driven learning is likely to be most effective in accelerating decarbonisation in the concrete sector. While voluntary agreements like the Betonakkoord provide a useful starting point, long-lasting change will require systemic coordination and targeted investment across the concrete value chain.

6.3. Limitations

This study was designed as an exploratory, qualitative inquiry, offering depth and contextual insight into how concrete companies interpret and respond to decarbonisation strategies. While the sample included a diverse mix of company types from proactive innovators to more pragmatic actors; the goal was to capture a range of lived experiences and systemic constraints. Nine interviews identifed thematic saturation for this type of case-based research. However, additional interviews within each company type could have provided more detailed comparative insights.

While the study included participants from a variety of organisational roles such as sustainability officers, technical managers, and business owners, not all relevant stakeholder groups were represented. Due to time and scope constraints, government actors, certification bodies, and sector associations were not included. Their inclusion could have provided a richer institutional perspective, especially regarding policy enforcement, compliance dynamics, and regulatory alignment.

Language presented another consideration. As Dutch is not the researcher's first language, but Dutch was native to the participants, care was taken to ensure clarity and accuracy throughout the data collection and analysis process. For the first four interviews, two technical supervisors (one Dutch-speaking and one English-speaking) were present to accommodate unknown language preferences and ensure that no meaning was lost. After initial interviews, supervisors remained present based on the language of the session (the Dutch-speaking supervisor joined interviews conducted in Dutch, and the English-speaking supervisor participated in English-language interviews). This approach helped maintain clarity and participant comfort but also introduced subtle differences in facilitation style and follow-up questioning.

In addition, there were noticeable differences between physical and online interviews. While all interviews followed the same protocol, in-person interviews tended to yield richer contextual cues and more spontaneous dialogue, whereas online sessions were occasionally affected by connection issues or a more formal tone. These mode-related variations may have influenced the depth of some responses.

Finally, the researcher’s position as a thesis intern at a 3DCP startup may have shaped the thematic emphasis of the study. While neutrality was maintained throughout data collection and analysis, this insider perspective may have led to increased attention to innovation, automation, and material experimentation within the interpretation process. Despite these limitations, the study provides grounded, practice-based insight into how Dutch concrete companies navigate the tension between sustainability ambition and operational feasibility. It highlights areas where greater alignment between procurement, policy, and organisational support could accelerate meaningful progress.

7. CONCLUSION

7.1. Summary of Main Insights

This study examined how companies in the Dutch concrete sector engage with sustainability and innovation in response to decarbonisation targets. Using the Concrete Agreement and its accompanying Road Map CO_2 as reference points, the research investigated how voluntary frameworks are interpreted and operationalised across a diverse set of firms. Interviews with nine organisations and 10 participants revealed that while awareness of the Concrete Agreement varied, companies were more strongly influenced by market dynamics, particularly public procurement rather than by sector-wide agreements.

The role of key clients, especially municipalities, emerged as the most significant factor in shaping the adoption of low-carbon strategies. Participants consistently reported that sustainability actions were most likely to be pursued when embedded in tender criteria or linked to reputational value. Key barriers included inconsistent procurement standards, unclear certification procedures, and cost constraints. Nonetheless, enablers such as MKI-based tendering, coordination from sectoral platforms like Betonhuis, and internal leadership commitment contributed to positive outcomes in select cases.

Importantly, innovation readiness was not solely determined by technical capability. Organisational culture, perceived business value, and external policy signals also played critical roles. Sustainability was typically approached as a matter of client-driven compliance or strategic positioning, rather than as a long-term transformation imperative. This suggests that while incremental progress is being made, the implementation of low-carbon practices remains inconsistent and conditional.

7.2. Theoretical and Practical Contributions

This research contributes to the academic literature on sustainability transitions by demonstrating how decarbonisation efforts in the concrete sector are mediated not only by policy directives but also by organisational interpretation and systemic alignment. Applying the PROMISE framework enabled a nuanced analysis of how structural factors ranging from policy ambiguity to procurement design, leadership, and socio-technical conventions had influenced innovation trajectories.

From a practical standpoint, the findings offer insights for policymakers, municipal clients, and industry bodies seeking to close the gap between ambition and implementation. Voluntary frameworks such as the Betonakkoord can help set a shared direction, but without regulatory consistency, procurement pressure, and accessible certification tools like MKI, their ability to drive sector-wide change remains limited. To advance more systemic uptake of low-carbon practices, it is critical to reward early adopters, de-risk innovation pilots, and support platforms that facilitate peer learning and standard-setting.

The study also highlights the potential of emerging technologies such as 3DCP, which offer new pathways for circularity and automation. However, such innovations require targeted support through clearer certification routes, funding mechanisms, and client-side engagement to transition from niche to mainstream practice.

Future research could expand this inquiry by exploring client-side procurement behaviour, comparing transition dynamics across national contexts (e.g., Belgium or Germany), or evaluating how upcoming revisions to Dutch procurement legislation may influence innovation adoption in high-carbon industries.

8. REFERENCES

Betonhuis. (2025, May 1). *Betonhuis*. Betonhuis. https://betonhuis.nl/

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Byrne, D. (2022). A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Quality & Quantity*, *56*(3), 1391–1412. https://doi.org/10.1007/s11135-021-01182-y

Concrete Sustainability Council. (n.d.). *Certification*. Retrieved 10 May 2025, from https://csc.eco/certification/

Council of the European Union. (2021). *Fit for 55: Delivering the EU's 2030 Climate Target*. European Council – Council of the European Union. https://www.consilium.europa.eu/en/policies/fit-for-55/

Cramer, J. (2020). *How network governance powers the circular economy: Ten guiding principles for building a circular economy, based on Dutch experiences*. Amsterdam Economic Board.

Cramer, J. (2021). *The transition to sustainable concrete in the Netherlands through network governance*. 21–24. https://doi.org/10.2749/ghent.2021.0021

Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (3rd ed.). Sage Publications.

European Commission. (2019). *EU Green Deal: Commission presents roadmap for climate-neutral Europe by 2050*. European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

Foundation for Climate Friendly Procurement and Business (SKAO),. (2025a). *CO_2 Performance Ladder: Step 1 (Version 4.0)* (Handbook No. Step 1 – Version 4.0). SKAO. https://www.co2performanceladder.com/documents/co2-performance-ladder-version-4-0-step-1/

Foundation for Climate Friendly Procurement and Business (SKAO),. (2025b). *CO_2 Performance Ladder: Step 2 (Version 4.0)* (Handbook No. Step 2 – Version 4.0). SKAO. https://www.co2performanceladder.com/documents/co2-performance-ladder-version-4-0-step-2/

Foundation for Climate Friendly Procurement and Business (SKAO),. (2025c). *CO_2 Performance Ladder: Step 3 (Version 4.0)* (Handbook No. Step 3 – Version 4.0). SKAO. https://www.co2performanceladder.com/documents/co2-performance-ladder-version-4-0-step-3/

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, *1*(1), 24–40. https://doi.org/10.1016/j.eist.2011.02.002

Government of the Netherlands. (2019). *Climate Agreement*. https://www.government.nl/documents/reports/2019/06/28/climate-agreement

Habibi, A., Buswell, R., Osmani, M., & Aziminezhad, M. (2024). Sustainability principles in 3D concrete printing: Analysing trends, classifying strategies, and future directions. *Journal of Building Engineering*, *98*, 111354. https://doi.org/10.1016/j.jobe.2024.111354

International Energy Agency, International Renewable Energy Agency, & UN Climate Change High-Level Champions. (2023). *The Breakthrough Agenda Report 2023: Accelerating Sector Transitions Through Stronger International Collaboration*. International Energy Agency. https://iea.blob.core.windows.net/assets/d7e6b848-6e96-4c27-846e-07bd3aef5654/THEBREAKTHROUGHAGENDAREPORT2023.pdf

Jay, J. (2015). *PROMISE: A systems approach to sustainability strategy*. MIT Sloan School of Management. https://www.truevaluemetrics.org/DBpdfs/Metrics/MIT/Jason-Jay-SBwebinar-slides-2015-describing-MIT-PROMISE-framework.pdf

Kemp, R., Barteková, E., & Türkeli, S. (2017). The innovation trajectory of eco-cement in the Netherlands: A co-evolution analysis. *International Economics and Economic Policy*, *14*(3), 409–429. https://doi.org/10.1007/s10368-017-0384-4

Kivimaa, P., & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy*, *45*(1), 205–217. https://doi.org/10.1016/j.respol.2015.09.008

Kukah, A. S. K., Jin, X., Osei-Kyei, R., & Perera, S. (2025). Carbon Trading for the Construction Industry: A Systems Theory Approach. In M. Kioumarsi & B. Shafei (Eds.), *The 1st International Conference on Net-Zero Built Environment* (Vol. 237, pp. 1869–1880). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-69626-8_154

Rodrigo, M. N. N., Perera, S., Senaratne, S., & Xiaohua, J. (2019). *Embodied Carbon Mitigation Strategies in the Construction Industry*. https://www.researchgate.net/publication/333972724_Embodied_Carbon_Mitigation_Strategies_in_the_Construction_Industry

Schwartz, Y., Raslan, R., & Mumovic, D. (2018). The life cycle carbon footprint of refurbished and new buildings – A systematic review of case studies. *Renewable and Sustainable Energy Reviews*, *81*, 231–241. https://doi.org/10.1016/j.rser.2017.07.061

Sibileau, H., Vladyka, V., Fabbri, M., Jeffries, E., Milne, C., Rapf, O., & Toth, Z. (2024). *The EPBD Decrypted: A Treasure Chest of Opportunities to Accelerate Building Decarbonisation*. Buildings Performance Institute Europe (BPIE). https://managenergy.ec.europa.eu/publications/epbd-decrypted-read-new-report-bpie_en

van Gent, P. (2021, January 20). *Presentatie Stuurgroep, woensdag 20 januari 2021*.

van Oorschot, J., Sprecher, B., Rijken, B., Witteveen, P., Blok, M., Schouten, N., & van Der Voet, E. (2023). Toward a low‐carbon and circular building sector: Building strategies and urbanization pathways for the Netherlands. *Journal of Industrial Ecology*, *27*(2), 535–547. https://doi.org/10.1111/jiec.13375

van Tam, N., Toan, N. Q., & Ngoc, P. H. (2024). Key strategies for achieving net-zero carbon buildings and promoting carbon credits in construction markets: A case of an emerging economy. *Energy for Sustainable Development*, *81*, 101488. https://doi.org/10.1016/j.esd.2024.101488

9. APPENDICES

Appendix A: Interview Guide

Interview Guide (Sequential with Themes)

Facilitating Low-Carbon Innovation: The Role of the Concrete Agreement in the Dutch Construction Sector

1. Could you briefly introduce yourself and describe your role and responsibilities within your organisation?
2. How do you think sustainability is measured and applied in your company's operations?

Theme 1: Stakeholder Awareness and Interpretation

3. Where does your organisation typically receive information or guidance about sustainability frameworks or decarbonisation strategies?
4. Are you familiar with the Dutch Concrete Agreement and the Road Map CO_2?
 — If so, what is your view on its relevance or usefulness?

Theme 4: Implementation of Road Map CO_2

5. To better understand practical engagement, I'd like to go through a list of the 28 Road Map CO_2 action points.
 — For each, could you indicate whether it is: Testing ✅ Implemented ❌ Not implemented ❓ Not sure / Not relevant

Theme 2: Strategic and Policy Incentives

6. Have any of these measures led to financial benefits—such as cost savings, subsidies, tax advantages, or improved competitiveness?

Theme 5: Organisational Capabilities and Innovation Readiness

7. What internal factors (e.g., leadership, knowledge, budget) help or hinder your organisation in adopting low-carbon solutions?

Theme 3: Institutional and Market Barriers

8. What external barriers—like regulation, procurement rules, or incentive structure—have limited your ability to act on sustainability goals?

Theme 5: 3D Concrete Printing as a Case Lens

9. How do you see low-carbon technologies (e.g., 3D concrete printing, digitalisation) fitting into your long-term business strategy?

10. How do you feel about the goals and timelines in the Betonakkoord and Road Map CO_2 being realistic and/or achievable for your organisation?

11. Who do you see as leaders in low-carbon construction or innovation?

Closing

12. Closing: Do you have anything to add?

Appendix B: Consent and Ethics Forms

INFORMATION SHEET

Exploring Sustainability & Innovation in the Dutch Concrete Sector

Dear Interviewee,

Thank you for your interest in participating in this research. This letter explains what the study entails and how the research will be conducted. Please take the time to read the following information carefully. If any information is unclear, kindly ask questions using the contact details of the researchers provided at the end of this letter.

WHO AM I?
My name is Ryan Netto. As part of my MSc in Sustainable Entrepreneurship thesis at the University of Groningen, I am exploring how the Dutch Concrete Agreement influences low-carbon innovation in the construction sector.

WHAT IS THIS STUDY ABOUT?
This study investigates how the Concrete Agreement (*Betonakkoord*) supports or constrains the adoption of low-carbon innovations in the Dutch construction sector. The agreement provides voluntary strategies aimed at reducing carbon emissions in the concrete chain, including action points related to digital design, material reuse, and 3D concrete printing. You have been invited to participate because of your professional experience in this sector. Your insights will help understand how construction actors interpret and apply these strategies. The research is conducted as part of the Master's thesis at the University of Groningen, Campus Fryslân, under the practical supervision of Zavhy B.V.

AIM OF THE STUDY
To explore how the strategies promoted by the Concrete Agreement are understood, applied, and reflected in low-carbon innovation practices in the Dutch construction sector.

WHAT DOES PARTICIPATION INVOLVE?
If you agree to participate, you will be asked to take part in a semi-structured interview lasting approximately 45 minutes. The interview can be held in person or online, depending on the possibilities. With your permission, the conversation will be audio-recorded and later transcribed for analysis.

DO YOU HAVE TO PARTICIPATE?
Participation is entirely voluntary. You are free to decline to answer any questions and can withdraw from the study until it has been published (i.e., before the data you provided is analysed) without needing to give a reason. In that case, all the data provided by you will be destroyed. Please note that once data have been analysed, it may not be possible to remove your data from the study.

ARE THERE ANY RISKS IN PARTICIPATING?
There are no physical or psychological risks associated with participating in this research. Your identity will remain confidential.

ARE THERE ANY BENEFITS TO PARTICIPATING?
There are no direct personal benefits for participating. However, your insights will contribute to a better

understanding of how innovation and climate policy intersect in construction practice, especially for low-carbon transitions in construction.

HOW WILL THE INFORMATION YOU PROVIDE BE RECORDED, STORED, PROTECTED & USED?
All interviews, including audio recordings, transcripts, and consent forms (digital/physical), will be anonymised and stored securely on the University of Groningen's GDPR-compliant servers. Only the researcher and supervisor will have access to the raw data. Data will be kept for a maximum of 5 years and used exclusively for academic purposes. Upon request, you will be able to receive the final draft of the thesis developed with the data you provided, once it is completed. The results will be included in a master's thesis, and potentially in academic publications, industry white papers and/or conference presentations. No identifying information will be included in any output.

ETHICAL APPROVAL
This study has received ethical approval from the academic supervisor at Campus Fryslân, University of Groningen. All activities follow GDPR and academic ethical standards.

INFORMED CONSENT FORM
You may fill out the informed consent form and have the intention to participate while still being able to withdraw at any time.

WHO SHOULD YOU CONTACT FOR FURTHER INFORMATION?

Primary Researcher:
Ryan Netto – MSc Sustainable Entrepreneurship
University of Groningen
r.a.netto@student.rug.nl

Academic Supervisor:
Rimvyde Muzikeviciute - PhD Candidate
University of Groningen
r.b.muzikeviciute@rug.nl

Internship Supervisor:
Zeeshan Ahmed,
CEO Zavhy B.V.
zeeshan@zavhy.com

Thank you for your participation.

CONSENT FORM

Exploring Sustainability & Innovation in the Dutch Concrete Sector

By participating in this study:	**Yes**	**No**
I am aware that my participation is entirely voluntary and carries no personal benefit.		
I am aware that the research will be conducted in English for data analysis.		
I may stop participating in the study at any time until 5 June without giving reasons. This does not entail any consequences.		
I understand that once the data analysis has started, it may not be possible to remove my data from the study.		
I will remain anonymous in the transcription of a semi-structured interview and analysis of the data.		
I am aware that the results of the study will only be used for strictly educational and research purposes.		
I authorise to be quoted in the research publication under a pseudonym.		
I consent to the interview being audio recorded.		
I am aware that the data will be stored safely and securely.		
The draft of the publication, developed with the data provided, will be sent to the participant upon request.		

○ **Yes, I want to participate in this study and agree with the information outlined above.**

Name of Participant:

Date: **Signature:**

Name of Researcher: Ryan Netto

Date: **Signature:**

Appendix C: Thematic Coding Structure

Action	Roadmap CO_2 Description	Roadmap CO_2 Omschrijving	Testing	Implemented (Y)	Not Implemented (N)	Not Applicable (N/A)
1	Optimize the grain size distribution of aggregates to reduce voids and minimize cement use.	Optimaliseer korrelverdeling van toeslagmaterialen om holle ruimtes te beperken en cementgebruik te verlagen.				
2	Use low-CO_2 Belite clinker cement types like CSA or BCT to reduce emissions in cement production.	Gebruik Beliet-gebaseerde cementen zoals CSA of BCT met lagere CO_2-uitstoot bij productie.				
3	Apply alternative binders like Solidia that absorb CO_2 during curing for additional environmental benefits.	Pas alternatieve bindmiddelen toe, zoals Solidia, die CO_2 opnemen tijdens het uitharden.				
4	Implement carbon capture technologies at cement plants to reduce process emissions.	Voer CO_2-afvang uit bij cementproductie om procesemissies te verminderen.				
5	Use geopolymers made from industrial by-products as low-carbon alternatives to traditional cement.	Gebruik geopolymere bindmiddelen op basis van reststoffen als alternatief voor cement.				
6	Design buildings and elements for future disassembly and reuse instead of demolition.	Ontwerp gebouwen en elementen zodanig dat toekomstige demontage en hergebruik mogelijk is.				
7	Repurpose or renovate existing concrete structures to avoid new material production.	Herbestem of renoveer bestaande betonconstructies om nieuwe materiaalproductie te vermijden.				
8	Promote carbonation of recycled cement paste to reabsorb CO_2 released during its initial production.	Stimuleer carbonatatie van gerecyclede cementsteen om CO_2 opnieuw op te slaan.				
9	Replace clinker in cement with fillers like limestone or calcined clay to lower carbon intensity.	Vervang klinker door vulstoffen zoals kalksteenmeel of gecalcineerde klei om CO_2 te reduceren.				
10	Plan construction schedules to avoid winter pours that require more cement and energy.	Plan bouwactiviteiten om betonstort in wintermaanden te vermijden en cementverbruik te beperken.				
11	Extend the service life of concrete infrastructure to reduce the need for new construction.	Verleng de levensduur van infrastructuur om nieuwe bouwprojecten uit te stellen.				
12	Use reactive fillers from bottom ash to partially substitute cement in concrete mixes.	Gebruik reactieve vulstoffen uit bodemas als gedeeltelijke cementvervanger.				
13	Use fly ash as a cement substitute to reduce clinker content and emissions.	Gebruik vliegas om een deel van het cement in mengsels te vervangen en uitstoot te verlagen.				
14	Apply chemical accelerators to shorten curing time and enable lower cement dosages.	Gebruik versnellers om uithardingstijd te verkorten en minder cement nodig te hebben.				

15	Reduce embedded CO_2 in concrete by sourcing low-emission steel for reinforcement (external).	Beperk CO_2 in beton via gebruik van staal met lagere emissies (buiten betonsector).				
16	Reduce energy consumption in concrete plants through process optimization and electrification.	Verlaag energieverbruik in betoncentrales via optimalisatie en elektrificatie.				
17	Use concrete's thermal mass in building design to reduce energy needs in use phase (BKA).	Gebruik de thermische massa van beton in gebouwen om energieverbruik te beperken (BKA).				
18	Ensure reliable supply of blast furnace slag, a key material in low-CO_2 cement mixes.	Zorg voor continue beschikbaarheid van hoogovenslak als essentieel onderdeel van CO_2-arm cement.				
19	Use structural design methods to reduce overuse of materials and optimize dimensions.	Optimaliseer ontwerp om materiaalgebruik te beperken zonder in te leveren op prestaties.				
20	Apply 3D printing for structural elements to reduce formwork and use material only where needed.	Gebruik 3D-printtechnologie voor constructieve elementen en voorkom materiaalverspilling.				
21	Use fiber or non-steel reinforcement to reduce material and corrosion-related emissions.	Gebruik alternatieve wapening zoals vezels om staalverbruik en corrosierisico te verlagen.				
22	Apply slow-curing concrete where time allows, reducing the required cement content.	Pas langzamer uithardend beton toe om cementdosering te beperken bij geschikte toepassingen.				
23	Use concrete's overstrength to reduce material in structural elements when feasible.	Gebruik oversterkte in beton optimaal om slankere ontwerpen te realiseren.				
24	Use calcined clay as a supplementary cementitious material to replace part of the clinker.	Gebruik gecalcineerde klei als aanvullende cementvervanger in mengsels.				
25	Use Carbstone, a material that captures and permanently stores CO_2 during curing.	Gebruik Carbstone, dat tijdens het verhardingsproces CO_2 opslaat.				
26	Reuse entire precast concrete elements in new construction where feasible.	Hergebruik volledige prefab betonelementen in nieuwe toepassingen waar mogelijk.				
27	Improve transport and logistics efficiency to reduce emissions across the concrete supply chain.	Verbeter logistiek en transportefficiëntie om CO_2-uitstoot in de keten te verminderen.				
28	Use self-healing concrete that repairs cracks with embedded agents, extending service life.	Gebruik zelfherstellend beton dat scheuren repareert en de levensduur verlengt.				